graphed continuously on a revolving plate, so that the nature of the disappearance, whether instantaneous or gradual, could be recorded.

Numerous valuable observations of peculiar stellar spectra were made during the year, including the discovery of Nova Aquilæ No. 2 by Mrs. Fleming. This is the eighth Nova discovered by that observer from the Draper memorial spectrograms.

With the Bruce telescope 523 plates were obtained, making 7504 in all, from which Miss Leavitt has discovered 1129 new variable stars during the year.

The bibliography of variable stars compiled by Miss Cannon was nearly ready for publication when the Astronomische Gesellschaft appointed a committee to undertake a similar work. Prof. Pickering therefore proposes to publish the Harvard work in an abridged form.

CATALOGUE OF 3799 BRIGHT STARS.—A useful catalogue of 3799 bright stars has just been published by M. J. Bossert, of the Paris Observatory.

This catalogue gives the magnitude and mean coordinates (1900·0) of each star, and, in addition, the precession, secular variation, and proper movement, together with instructions and examples for finding the star's position at any given epoch.

The stars are arranged in zones of 1° of N.P.D., and in each zone they are given in order of R.A., this classification being considered the most convenient for meridian observers.

Stars down to the seventh magnitude are included, the magnitude of Aldebaran being taken as 1·0.

ECLIPSE OBSERVATIONS AT CATANIA.—On the occasion of the total solar eclipse of August 30, 1905, observations of prominences, by the Lockyer-Janssen method, and of the variations in the terrestrial electric field were carried out, during the whole day, at the Catania Observatory.

The results are published in No. 1, vol. xxxv., of the *Memorie della Società degli Spettroscopisti Italiani*, and show, among other things, that the maximum effect of the solar radiation corresponds to the minimum potential of the atmospheric electricity.

MICROMETER MEASURES OF STRUVE DOUBLE STARS.—No. 4078 of the *Astronomische Nachrichten* contains the results of a series of measures of eighty-one "Struve" double stars made by Dr. H. E. Lau, of the Copenhagen University Observatory.

The position for 1900·0, the position-angle, the distance, and the data and hour of each observation are given for each star, and are followed by brief notes by the observer.

SOME APPLICATIONS OF THE THEORY OF ELECTRIC DISCHARGE THROUGH GASES TO SPECTROSCOPY.[1]

THE luminosity produced by an electric current passing through a gas at low pressure varies greatly in character, not only when we alter the nature of the discharge, as, for example, when we pass from the arc to the spark, but also in many cases at different points of the same discharge. The luminosity may be of one colour at one place and of a very different colour at another, and spectroscopic examination shows that the spectrum of the same gas often varies considerably as we proceed along the line of discharge. As recent experiments have thrown a considerable amount of light on the processes going on in the different kinds of electrical discharge and at different parts of the same discharge, the study of the connection between the changes in the electrical effects and the changes in the spectra might be expected to throw some light on the very interesting question of the genesis of spectra. Many important points can very conveniently be studied by the aid of Wehnelt's method of producing the current. In this method the kathode is a strip of platinum or a piece of platinum wire on which either a little lime or barium oxide has been deposited. This when heated to redness emits large supplies of corpuscles, and by altering the temperature of the platinum very large variations in the current passing through the tube and in the potential difference between the electrodes can be obtained. In our experiments the current varied from a small fraction of a milliampere to several amperes, and the potential difference from a few volts to several hundred.

The apparatus used is shown in Fig. 1. AB is the platinum strip with the lime on it; a thermocouple—a platinum and platinum-rhodium junction—was fused to this strip, and served to determine its temperature; the strip was connected with the earth, and was heated by a current passing through the leads LM; a rheostat was placed in series with the heating current, and by means of this the temperature could be altered gradually. The anode was a platinum disc; this was connected with the positive pole of a battery of storage cells, the negative pole of which was earthed; to allow of gradual variations in the potential difference between the electrodes a potential divider of 100 resistances of 10 ohms each was used. The current through the tube was measured by a d'Arsonval galvanometer, and the potential difference between the terminals by a Weston's voltmeter.

Some of the most interesting features of the discharge are very prominent when the temperature of the platinum is high, say 1400° C., and the pressure of the gas low, less than 0·01 mm. of mercury. The discharge is light

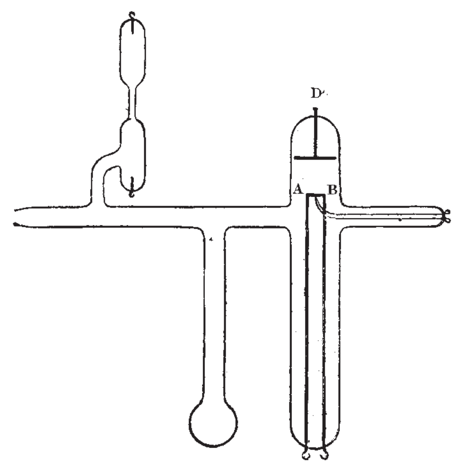

FIG. 1.

blue, and its spectrum shows the mercury lines and the band spectrum of nitrogen. In this case the relation between the current and the potential difference is represented by a curve like Fig. 2, the ordinates representing the current and the abscissæ the potential difference. In the case we are considering, when the wire is very hot and the pressure low, the change from the dark to the luminous discharge takes place very abruptly, an increase of the potential difference by 1/100 of a volt being often sufficient to convert a discharge where no light could be detected even in a darkened room into one where the light was quite bright. When luminosity appears there is a very rapid increase in the current; in some of the experiments an increase in the potential difference of 1/100 of a volt increased the current forty-fold. At this stage the thermojunction showed that there was no increase in the temperature of the platinum where the luminosity appeared; we shall see later on that it is possible by using large potential differences to get such large currents through the tube that the platinum becomes appreciably warmer by the passage of the current.

One point which I think very suggestive is the abruptness with which the luminosity round the kathode appears. We see that by a very small increase in the potential difference the discharge passes from a state in which no luminosity can be detected, even in a dark room, to one where the luminosity can plainly be seen in a bright light; thus the molecules of the gas in the tube, just when the luminous discharge is on the point of appearing, are in a state in which a very small change in the electrical

[1] Discourse delivered at the Royal Institution on Friday, January 19, by Prof. J. J. Thomson, F.R.S.

conditions of the tube makes the molecules pass from a condition in which they are not giving out an appreciable amount of light to one where they are brightly luminous, and, as the great increase of the current when the luminosity appears shows, this change in state is accompanied by an emission of corpuscles. From this and other considerations I have come to the conclusion that what takes place when the gas becomes luminous is that the

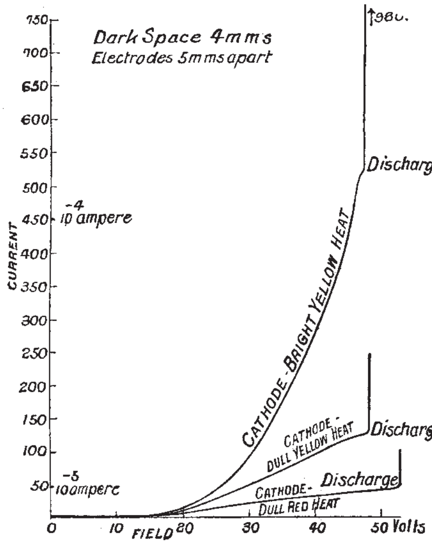

FIG. 2.

internal energy in the atom, in consequence of its bombardment by the corpuscles, increases, and when it gets up to a certain critical value the equilibrium of the atom becomes unstable, an explosion occurs resulting in an expulsion of corpuscles, and such a shaking up of those left in the atom that these vibrate so vigorously that the energy radiated is sufficient to produce luminosity. Thus I regard the ionisation of the gas as being due, not to the corpuscles in the atom being dragged out by the direct action of the electric forces in the field, or as being knocked out by a rapidly moving corpuscle striking against them, but to an explosion due to the atom having absorbed so much internal energy that its equilibrium becomes unstable. Other phenomena point to this as the method by which ionisation is effected. If the corpuscles are dragged out of the atoms by the electric field, the velocity with which they are projected should depend upon the strength of the field; while if they are projected by an explosion their velocity would depend only upon the nature of the atom, and not upon the strength of the field. Now when Röntgen rays fall upon a substance the atoms of the substance are ionised, and corpuscles are emitted forming a stream of kathodic rays. Barkla has lately shown, however, that the penetrating power of the kathodic rays produced in this way is independent of the intensity of the Röntgen rays. Now the electric force in the Röntgen rays depends upon their intensity, and the penetrating power of the kathodic rays depends upon their velocity, so that this result shows that the velocity of the corpuscles does not depend upon the intensity of the force acting upon them. Again, Lenard has shown that the velocity of the corpuscles ejected when ultra-violet light falls upon a metal is independent of the intensity of the light. Lenard also investigated the secondary kathode rays produced when kathode rays fall upon matter, and found that, in addition to rays the velocity of which was of the same order as that of the primary rays, and which may be regarded as deflected primary rays, there were other very slow rays, and the measurements he gives indicate that the velocity of these varies but little from that of the primary rays.

A point of great importance which can easily be shown by this apparatus is that the stage at which luminosity sets in depends upon the current density through the tube, and not merely upon the potential difference. One way of showing this is to lower the temperature of the platinum, keeping all the other conditions the same, and again determine the relation between the current and the potential difference. The effect of lowering the temperature is to reduce the number of corpuscles starting from the kathode, so that with the same potential difference the current density is smaller. If the relation between the current and potential difference is represented by a curve such as Fig. 3, it will be seen at once that the lower curve cannot be deduced from the upper curve by reducing all the ordinates in the same proportion. The critical points on the curves, *i.e.* the place where ionisation by collision begins and where the luminous discharge appears, are at very different potentials: the greater the current density the smaller the potential difference corresponding to these critical points. Thus, to take a case actually observed. When the wire was very hot the discharge was brightly luminous with a potential of 24 volts; on lowering the temperature no luminosity could be detected with a potential difference of 110 volts.

We can also show the effect of current density without altering the temperature of the kathode by placing near the tube an electromagnet so arranged that its lines of magnetic force in the discharge tube are along the line joining the kathode and the anode; the effect of the magnetic field is to make the corpuscles move along the lines of force, and thus without altering the number of corpuscles emitted by the kathode it concentrates their paths and so increases the maximum current density in the tube. When the magnet is on, ionisation by collision and luminosity both occur at a much lower potential difference than when it is off, and it is easy to arrange matters so that, keeping the potential difference constant, the discharge is luminous when the magnet is on and dark when it is off. When the potential difference is too small to produce a bright discharge even when the magnet is on, the current through the tube is often greater when the magnet is on than when it is off. By placing the magnet so that the lines of magnetic force are across the line joining the kathode to the anode we can render the paths of the

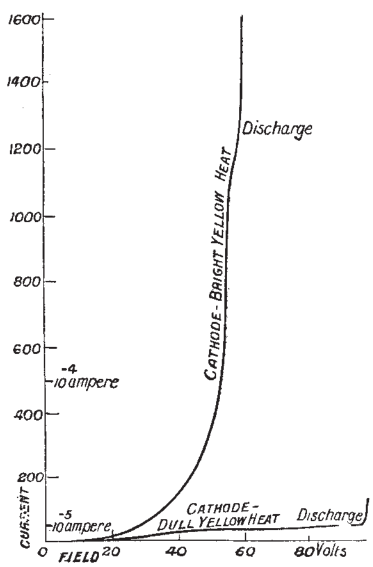

FIG. 3.

corpuscles more diffuse than they would be without the field, so that the maximum current density is less when the magnet is on than when it is off; in this case it requires a larger potential difference to produce a luminous discharge with the magnet on than with it off. Similar effects produced by a magnet on another kind of discharge are described in my "Recent Researches," p. 105.

The potential difference P just where the glow commences, when the pressure is low, sometimes varies so rapidly with the current i as to be roughly inversely proportional to it. The following are some values of i and P for a gas at a constant low pressure as the temperature of the platinum strip was increased; the numbers are in the order of increasing temperature:—

(in scale divisions)	P (volts)	Pi
6	60	360
8·7	40	348
11·2	30	336
14	25	350

Such a simple relation between P and i is, however, exceptional.

The fact that the potential differences at which ionisation by collision or luminosity begins depend upon the current density, shows that the ionisation or luminosity of an atom need not, and, indeed, cannot entirely, be the result of a *single* collision between a corpuscle and the atom. For if that were the case, then since the energy of the corpuscle depends only upon the electric field, and not upon the current density, the effect of increasing the current density would merely be to increase in the same proportion the number of luminous atoms, while, as a matter of fact, if the potential difference is kept constant and the current increased by raising the temperature of the platinum strip the increase in the luminosity is greater out of all proportion than the increase in the strength of the current.

The result, however, is easily explained if we look at the question from the following point of view. Suppose that for ionisation or luminosity to take place the internal energy of the atom must increase by certain amounts, say E_1, E_2 respectively. Then, if the energy possessed by the corpuscle were very great, the result of one collision with an atom might be to give to the atom enough energy to ionise it or make it luminous, or both. But even if the corpuscle were less energetic, and did not in one collision give enough internal energy to the atom to ionise it, it would communicate some energy to it, and if the atom had any power of storing up energy this would form a contribution towards the critical amount of energy required by the atom before it is ionised. The atom, after having had this energy communicated to it, would, so long as it retained any of it, not require so much energy to ionise it as before. The atom, too, might acquire energy, not merely by corpuscles striking against itself, but also by the collision of corpuscles with neighbouring atoms; such collisions generate soft Röntgen rays, the energy of which might be absorbed by the atom under consideration and help to raise its energy to the critical point; the energy in the Röntgen rays might by itself raise the internal energy of the atom to this value, or else raise it so nearly to this value that the collision with a corpuscle would give it enough energy to carry it past the critical stage. The rate at which the energy, due to collisions of corpuscles with itself or with neighbouring atoms, comes to an atom will be proportional to the rate at which energy is being communicated to the gas, *i.e.* to Fi, where F is the electric force and i the current density, and thus for a constant electric force would be proportional to the current density. The atom will radiate away some of its internal energy; if the rate of this radiation is proportional to the amount of energy, E, possessed by the atom, say equal to βE, then if q is the rate at which energy is being communicated to the atom, we have

$$dE/dt = q - \beta E,$$

so if E vanishes with t,

$$E = q/\beta\,(1 - e^{-\beta t}.$$

Thus q/β is the limit to the energy acquired by the atom, and this is proportional to q, while q is proportional to Fi, so that the atom will acquire the critical amount of energy or not according as Fi is greater or less than a certain value.

Application of these Results to Spectroscopy.—We have seen that the passage from the dark to the luminous discharge occurs with great abruptness, an increase of the potential difference by 1/100 of a volt being sufficient in certain circumstances to convert a discharge in which no luminosity at all could be detected to one where it was quite bright. This suggests that the luminosity sets in when the internal energy of the atom, or rather of that part of it which gives rise to the particular kind of light present in the luminous discharge, attains a perfectly definite value. This way of regarding the origin of the luminosity affords a very simple explanation of the variation of the spectrum with the kind of discharge and of the effect of introducing capacity or self-induction into the circuit containing the discharge tube. Let us consider the rise in energy of a vibrating system inside the atom; let E be the energy at the time t, α the rate at which it is absorbing the work done in the discharge tube; the energy may be supplied to it from the Röntgen radiation in the tube or from the corpuscles which come into collision with the atom, α will be proportional to the rate at which the electric field producing the discharge is doing work in the neighbourhood of the atom we are considering; it will thus be proportional to the product of the electric force and the flux of corpuscles in this neighbourhood. Let us suppose that the system radiates energy at a rate proportional to E, say equal to βE, then we have

$$dE/dt = \alpha - \beta E,$$

or

$$E = \alpha/\beta\,(1 - e^{-\beta t})$$

if E = o when t = o.

Consider two different systems, A and B, in the same atom; let E_1, α_1, β_1; E_2 α_2, β_2 be the values of E, α, β for the systems A and B respectively.

$$E_1 = \alpha_1/\beta_1\,(1 - e^{-\beta_1 t}),$$
$$E_2 = \alpha_2/\beta_2\,(1 - e^{-\beta_2 t}).$$

Now suppose that the system A is one that does not absorb much, but also does not radiate much, while B absorbs a great deal more than A, but radiates still

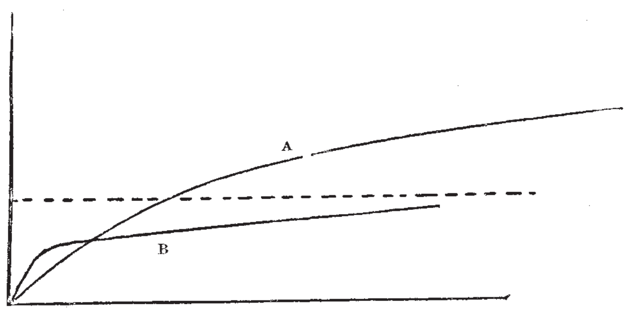

FIG. 4.

more in proportion, so that $\alpha_2 > \alpha_1$ but $\alpha_1/\beta_1 > \alpha_1/\beta_2$, then ultimately E_1 is greater than E_2, but at first E_2 is greater than E_1. The curves A and B, Fig. 4, represent the variations of E_1 and E_2 with the time.

Suppose, now, that systems A and B become luminous when the internal energy is equal to W. It is not necessary to assume that the critical amount of energy is the same for the two systems; the assumption is only made to simplify the diagram; it will be seen that the argument will apply if the critical amounts of energy are different in the two cases.

Now consider, first, the case when the rate at which work is being done in the tube is so small that though α_1/β_1 is greater than W, α_2/β_2 is less than W, the case represented in Fig. 4; here system A acquires the amount of energy necessary to make it luminous, while system B does not; thus in this case the spectrum of the gas would show the lines corresponding to A, but not those of B. Suppose, now, we increase the rate at which work is done in the tube, so that both α_2/β_2 and α_1/β_1 are greater than W, the case represented in Fig. 5.

Here the system B attains the critical amount of energy, and it reaches this value before A does so, so that in this case the lines of B will be visible. Let us now consider the lines in the spectrum corresponding to the system A; these will be visible if the energy in the system reaches the critical value. The conditions in this case are in some respects more unfavourable for the supply of energy to

this system than they were in the previous one. For in the first case the system B got into the condition in which it radiated as much energy as it received, and thus did not absorb any of the energy; in the second case, however, B became luminous before its radiation was equal to the absorption; it is thus taking in more energy than it gives out, and this may result in a diminution in the rate of supply of energy to A. It would be so, for example, to a marked extent if the conditions were such that A received a considerable portion of its supply of energy from B; this diminution in the supply might be great enough to prevent the internal energy in B reaching the critical value. Thus the effect of the increase on the rate of supply of the electrical energy might be to weaken, or even obliterate, the lines of A, and while with the smaller rate we had the lines of A and not those of B, with the larger rate we might have the lines of B and not those of A; thus an increase in the rate at which the electric field is doing work such as would be produced by increasing the current through the discharge tube might result in an entire change of the spectrum. We should expect that it would only be in exceptional cases that the lines of A would be obliterated under the conditions holding in case 2, but in all cases the increase in the brilliancy of the lines of B would be large compared with the increase of those in A.

We see from the equations giving E_1 and E_2 that until the supply of energy has lasted for a time comparable with $1/\beta_2$, E_2 is large compared with E_1; thus for electrical discharges which last for an exceedingly short time we might easily have the lines of B visible and not those of A.

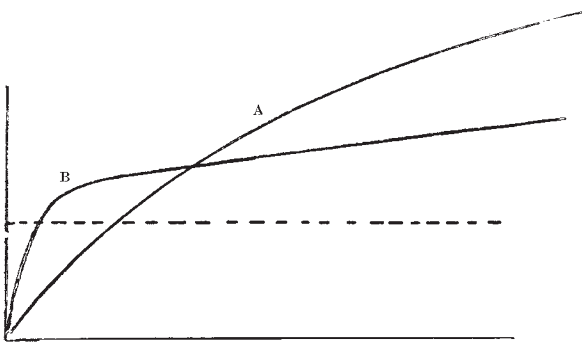

FIG. 5

In a discharge tube conveying an electrical current the amount of work per unit volume of the gas done by the electrical forces per unit time varies very largely from one point of the tube to another; if the cross section of the discharge is the same at all parts of the tube, so that the current density is uniform, the rate at which the electrical forces do work will be proportional to the electric force; as this is much greater near the kathode than at other parts of the tube, we should expect the lines of systems of the type B to preponderate near the kathode, and to be absent or much feebler in other parts of the tube. If the tube were of the type frequently used for spectroscopic purposes with a capillary portion in the middle, then since the current density is much greater in this portion than in any other, the rate of work per unit volume of the gas will be much greater in the capillary portions than in the wide parts of the tube, and we should therefore expect the lines of systems of the type B to be much more prominent in the capillary part than in the wide part.

Effect of Self-induction and Capacity.—Suppose that we have a tube of uniform bore arranged as in Fig. 6, the terminal of the tube being connected with the plates of a condenser of capacity C, and that there is a coil the coefficient of self-induction of which is L placed in series with the tube; then if the discharge through the coil begins when the potential difference between the plates of the condenser is V_0, the potential difference between the plates after a time t will be

$$V_0 \cos pt,$$

and the current through the tube

$$CV_0 p \sin pt,$$

where $p = 1/\sqrt{LC}$.

Thus the maximum value of the product of the current and the potential difference, *i.e.* rate at which the electric forces are doing work in the tube, is $CV_0^2 p$ or $V_0^2\sqrt{C/L}$, and is thus proportional to the square root of the capacity and inversely proportional to the square root of the self-induction. Thus increasing the capacity increases the maximum rate of work, and therefore increases the brilliancy of the lines corresponding to systems of the type B relatively to those of type A, while inserting self-induction in the circuit increases the brilliancy of those of type A as compared with those of type B. If we suppose that the "blue" spectrum of argon corresponds to a system of type B, the red to a system of type A, we have an explanation of the changes in the spectrum of this gas, for by inserting capacity in the circuit we can change from the red to the blue spectrum, while having got the blue we can get back to the red by inserting self-induction. I have here a little model which is intended to illustrate the way in which the red and blue spectra of argon originate. It is based on the fact that when we send a current of electricity through a circuit the current

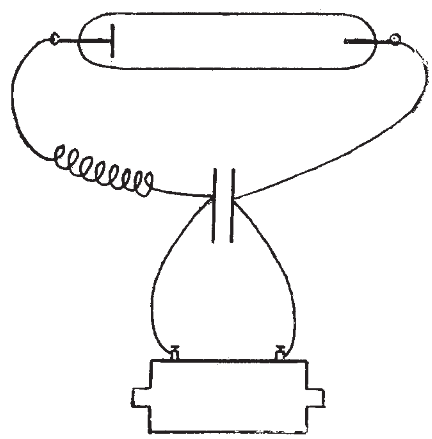

FIG. 6.

does not rise to its steady value instantaneously, but, starting from zero, increases with the time in exactly the same way as we have supposed the intrinsic energy in the atom, *i.e.* the way represented by the curve in Fig. 4. The quantity in the electrical case corresponding to the radiation β is the resistance of the circuit divided by the self-induction, while the quantity α is inversely proportional to the self-induction. Thus a circuit with large self-induction and small resistance is analogous to the system A, while one with small self-induction and large resistance is analogous to a system of type B. Now my model of the argon atom consists of two circuits, C and D, placed in parallel. C has large self-induction and small resistance, D has little self-induction but large resistance. An electric lamp is placed in each circuit. If I supply energy in one way, *i.e.* by continuous current, to the system, the red lamp in C lights up, the blue lamp in D is dark, while if fed by an alternating current the blue lamp shines and the red is dark. It would be interesting to see whether as we gradually diminish the self-induction we get the whole of the lines in the blue spectrum at once, or whether the lines of this spectrum enter in groups one after the other. I have tried somewhat similar experiments with the hot lime kathode to see in a mixture of gases, mercury vapour and air, which spectrum first appeared as the rate of doing work in the gas was gradually increased. The great difficulty in this determination is that when once

the luminosity begins there is such a rapid increase in the ionisation that the current through the gas and the rate of doing work increase in an exceedingly short time through a wide range of values, and thus a gradual increase in the rate of work is exceedingly difficult to obtain. On several occasions, however, I was convinced that on gradually increasing the rate of work the mercury lines were the first to appear, and were the last to disappear when the rate of work was reduced from a high value, at which both the nitrogen and mercury spectra were bright, down to a point where the discharge ceased to be luminous.

The preceding considerations have also an important application to the difference between the arc and spark spectra. In the continuous arc discharge, although the average rate of work is much higher than in the spark, the maximum rate is very much less; in the spark discharge we have an exceedingly intense current density lasting for a very short time, and while the spark is passing we have a very much greater rate of work than in the arc. Hence the state of things in the spark will be analogous to that represented in Fig. 5, and the lines corresponding to systems of the type B will be enhanced relatively to those of type A; we conclude, then, that the arc lines correspond to systems of the type A, the spark lines to those of type B.

The work done in the discharge tube is probably ultimately converted for the most part into heat, so that the rate at which work is being done at any part of the tube is approximately proportional to the rate at which heat is being produced in the tube. I do not, however, regard temperature, *i.e.* the energy due to the translation of the atoms as a whole, as having any direct connection with the production of spectra. The work done by the electric field on the corpuscles is, since the corpuscles can easily penetrate the atoms of the gas, first converted into internal atomic energy; this energy may ultimately be for the most part transformed into the energy of translation of the molecules of the gas, and so appear as temperature, but it by no means follows that if we heat the molecules of the gas by non-electrical means to the temperature to which even a few of its molecules are raised by the electric discharge we shall get a luminous spectrum. The production of the spectrum depends upon the internal energy of the atom; when we use the electric discharge all the work done by the corpuscles goes at first into the form of internal atomic energy, while if we supply the same amount of energy to the gas by thermal, as distinguished from electrical, means, the energy will go first into increasing the energy of translation of the atom, and very little of it will ever get inside the atom. It is probable, however, that some of the energy of translation will get converted into internal energy, and that temperature is one way of giving internal energy to the atom, and so producing luminosity; from our point of view, however, it is a very extravagant method, as the fraction of the energy spent in heating the gas which goes to produce luminosity is small.

The coefficient of absorption α of the systems will depend upon the way in which the internal energy is given to the atom as well as upon the rate at which the electric field is doing work in the neighbourhood of the atom. Thus, for example, if the internal work is given by means of rapidly moving corpuscles, the coefficient of absorption will depend upon the velocity of the corpuscle, for we can easily show that when a corpuscle passes at a fixed distance from a system of corpuscles having a definite period of vibration there is one velocity of the corpuscle, depending on this period, fast if the period is short, slow if it is long, for which the energy given by the corpuscle to the system is a maximum. Thus the relation between the amounts of energy absorbed by two systems from the corpuscles depends upon the velocity of the corpuscles. The velocity of the corpuscles in a discharge tube depends upon the pressure of the gas, so that even though the rate at which the electrical forces are doing work may be the same at two different pressures, the relative intensities of the lines of two systems A and B may be different.

Again, we might expect that the coefficient of the rate of absorption of energy would be different according as the energy is given to the atom by means of the large systems which form the positive ions or by means of small corpuscles, and that the relative brightness of lines might be different in the two cases. In the Kanal-strahlen we have positive ions moving through a gas and producing luminosity, and the spectrum of this luminosity possesses interesting peculiarities differentiating it from the spectrum of other parts of the tube. Perhaps the most striking difference, however, is when the positive ions strike against a salt like lithium chloride; they make the red lithium line appear with great brilliancy, while if corpuscles strike against the chloride the red line is not visible. It is remarkable that the spectrum of the metal is produced much more readily by the positive ions when they strike against a salt of the metal than when they strike against the metal itself; this is shown in a striking way if we take the liquid alloy of sodium and potassium and direct a stream of Kanal-strahlen upon it; the clean parts of the alloy appear quite dark, but the specks of oxide scattered over its surface shine with a bright yellow light, giving the sodium spectrum.

When the internal energy of the atom is increased by means of light, as in Prof. Wood's beautiful experiments on the fluorescence of sodium vapour, the coefficient of absorption of a system will depend upon the relations between the periods of that system and the period of the incident light vibrations; thus, as Prof. Wood found to be the case, the numerous lines in the spectrum given out by the vapour alter greatly in character and wave-length when the period of the incident light is changed.

The same principles which explain the variation in the intensities of the spectra given out by two different systems in the same atom can be applied to explain the variations in the intensities of the spectra of two gases, A and B, when these are mixed together. We know that under some conditions the lines of only one constituent of the mixture appear, while under others we get the lines of both the gases. Let us suppose that the lines of A appear with a lower rate of work of the electric forces than those of B, and that we send a constant current through the discharge tube, we can calculate what the electric force must be to produce from the molecules of A alone the number of ions required to carry this current; having found the electric force on this supposition, we can, knowing the current, find the rate at which the electric forces would be doing work in the tube; if this rate of work is less than that required to make B luminous, the current will be carried by the ions of A alone, and the spectrum of B will not be developed; if the rate of work on this supposition is greater than that required to make B luminous, the spectrum of B will appear, and it must take a share in carrying the current. Let us suppose that we have so much of A present that the rate of work is not sufficient to develop the spectrum of B, and consider what will happen as the proportion of A is diminished. In order to supply the number of ions required to carry the given current from the smaller number of molecules of A, the electric force, and therefore the rate of work in the tube, must, on the supposition that the current is wholly carried by A, increase, and if we continually diminish the amount of A present the rate of work will at last reach a value sufficient to make B luminous with the given current. This stage will give the smallest quantity of A which can for the given current wholly swamp the spectrum of B. The rate of work done in the tube will depend on the current going through it and also on the pressure of the gases, so that both these quantities will influence the proportion of the gas B required to make its spectrum visible.

MICROSCOPIC AQUATIC PLANTS AND THEIR PLACE IN NATURE.[1]

EVERY piece of water, besides containing large plants and animals which are readily visible to the naked eye, harbours a more or less considerable number of minute forms, which pervade all the layers of the water in varying amount, and collectively constitute the plankton or pelagic life. The most important difference between the

[1] Abstract of a lecture on "The Microscopic Plants of our Waters," delivered before the London Institution on February 1 by Dr. F. E. Fritsch.